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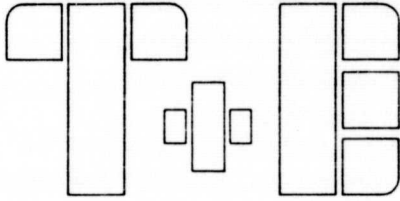
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FLAT CONDUCTOR CABLE
COMMERCIALIZATION PROJECT

Final Report

Contract #NAS8-31955

29 April 1977

Submitted to:

National Aeronautics and Space
Administration
George C. Marshall Space Flight Center
Huntsville, Alabama 35812



PREFACE

This report describes the activities of Technology + Economics, Inc. under Contract NAS8-31955, a Continuation Project to Apply Flat Conductor Cable to Building Wiring Systems from July, 1976 through January, 1977.

The objective of the project is to apply NASA-developed Flat Conductor Cable technology to building wiring. The project is under supervision of Marshall Space Flight Center, Huntsville, Alabama, originator of this technology.

NASA Staff involved in the project are as follows:

Mr. Aubrey Smith, MSFC Technology Utilization Officer

Mr. Ishmail Akbay, MSFC Technology Utilization Office,
Contract Monitor

Mr. James Carden, MSFC, Contract Technical Monitor

Mr. O. B. Hartman, NASA Headquarters, Technology
Utilization Office

Technology + Economics, Inc. wishes to thank in particular Mr. Akbay and Mr. Carden for their support and assistance throughout the course of the project.

Technology + Economics, Inc. Project Staff are as follows:

David J. MacFadyen, Project Director and Principal
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Peter T. Hogarth, Deputy Project Director

James R. Simpson, Senior Scientist

Ethel R. Wadsworth, Analyst

Karin Fantus, Secretary

This report emphasizes the activities of Technology + Economics, Inc., as opposed to the entire NASA effort. For a more complete description of NASA's activities, the reader is referred to the NASA report, NASA TN D-8540, "Development of Flat Conductor Cable for Commercial and Residential Wiring - Final Report". This report is available from the Marshall Space Flight Center Technology Utilization Office.

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INTRODUCTION

This report contains three sections plus an appendix. Section 1.0 is a background description of the Flat Conductor Cable (FCC). Commercialization Project. Section 2.0 provides a chronology and analysis of the undercarpet FCC project activity under this contract. Section 3.0 offers perspectives on the baseboard FCC system. Section 4.0 contains report appendices.

1.0 FLAT CONDUCTOR CABLE COMMERCIALIZATION PROJECT HISTORY

This project to apply Flat Conductor Cable technology to building wiring systems is an outcome of a more general ongoing project to apply aerospace technology to problems in the building industry. This project, known first as the Urban Development Applications Project, and later as the Urban Construction and Safety Project, has been active since 1970 as a Technology Application Team under NASA's Office of Technology Utilization.

One of the earliest problem areas identified by the Urban Development Applications Project was the area of building electrification. Existing wiring systems are expensive to install, difficult to modify and revise, and present safety hazards. In 1970 the Urban Development Applications Project began their search for NASA technologies that could be applied to these problems, and quickly identified the Flat Conductor Cable technology developed at Marshall Space Flight Center as a promising solution. Flat Conductor Cable, or FCC, uses wide, thin conductors instead of round ones, and can therefore be surface mounted on walls, floors, and ceilings. In appropriate applications, FCC wiring systems can result in significant cost reductions, in comparison to conventional solutions, and can be much more easily retrofitted and revised. In addition, there may be significant safety advantages in these systems. These result in part from the design and materials of the cable itself, and in part from the innovative connection technology that FCC implies.

Development and commercialization are being pursued for two FCC systems: an undercarpet system and a baseboard system.

The undercarpet FCC system is designed for (but not restricted to) installation in office and commercial buildings. It employs a flat power cable, protected by a grounded metal shield, that terminates in floor-mounted receptacles. It is designed to interface with a flat-conductor cable telephone system engineered by Western Electric. Advantages of the undercarpet FCC system include its elimination of expensive underfloor ductwork for new buildings, and its vastly simplified system revision for existing buildings.

The baseboard FCC system involves a flat power cable mounted in a plastic surface-mounted baseboard raceway with baseboard-mounted receptacles. Its potential applicability is primarily for residential work - particularly for renovation work and for concrete and masonry construction.

The T+E project staff has been involved for several years in an effort to find and mobilize manufacturers and potential system users to commercialize the systems. In the past year and a half, undercarpet and baseboard FCC were pursued as two independent projects.

The undercarpet project took the form of a major effort involving an industry group of ten manufacturers and system users. T+E's role in the undercarpet project passed from an initial advocacy role to a complex implementation management task involving the technical coordination of the ten private organizations plus NASA.

The project moved forward rapidly, on the strength of the interest shown by large users and on the magnitude of the potential market for the system.

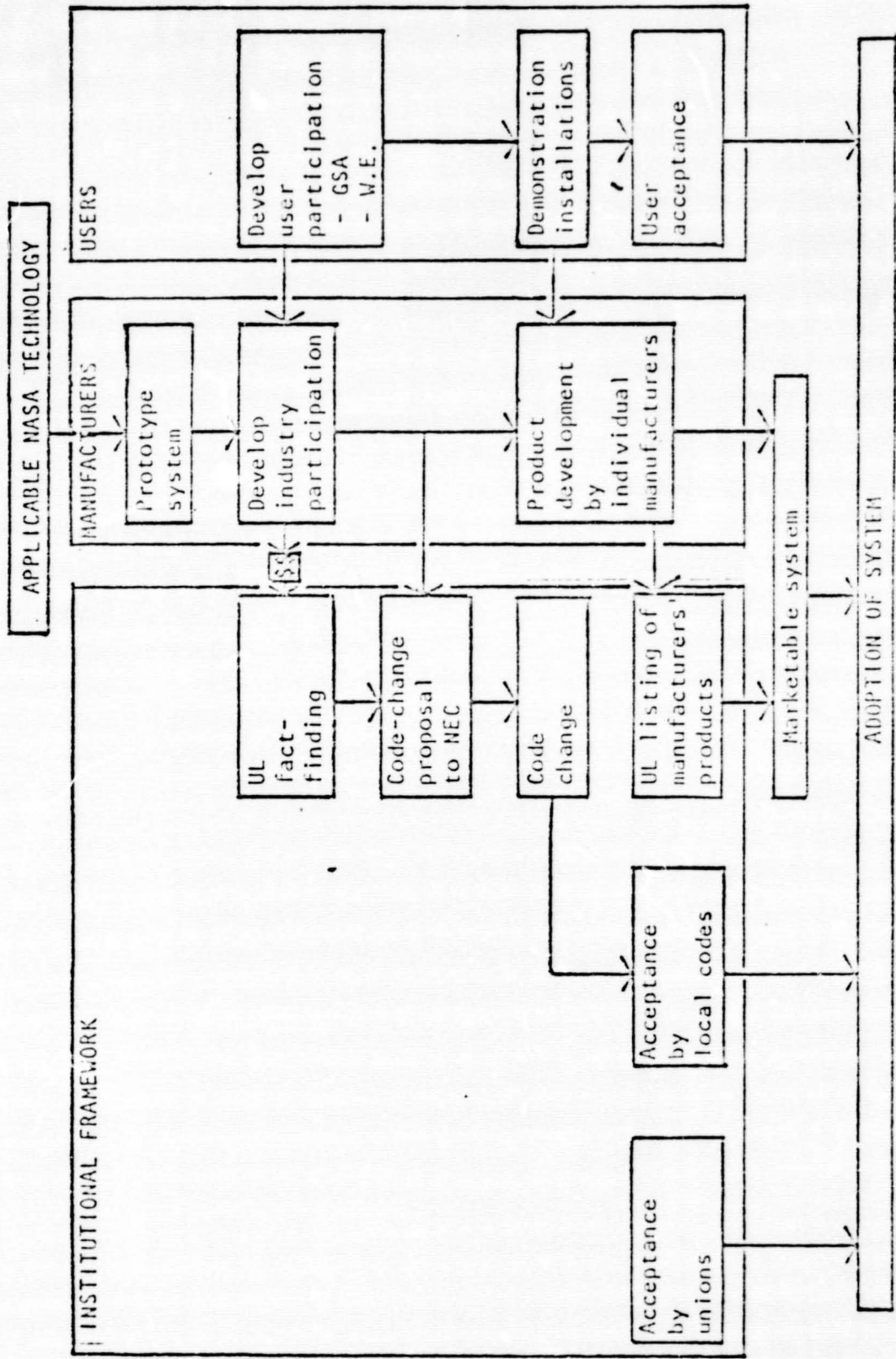
In 1975 and 1976 the undercarpet project focussed upon obtaining approval of the National Electrical Code (NEC) for the system. The current NEC does not allow FCC-type systems. Thus, project effort has been directed towards securing an NEC Code change to incorporate provisions for undercarpet FCC into the revised 1976 Code.

The chart on the following page depicts the commercialization road map for the undercarpet system. It can be seen in the diagram that, once past the Code change, the processes of system adoption will consist largely of human adaptations to change. Acceptance by unions, local codes, and ultimately, users, represents the requisite for successful commercialization.

Remaining manufacturer activity will involve product development by individual manufacturers to attain the required Underwriters' Laboratories listing of individual system components. This activity will ultimately result in various kinds of undercarpet FCC systems being available on the market. Listing of manufacturers' products will ensue once the Code change is formally adopted by the Electrical Section of the National Fire Protection Agency (NFPA).

In parallel with the undercarpet FCC project, initial work to develop commercial interest in the baseboard FCC system has occurred at T+E over the past several years. The baseboard system

FCC UNDERCARPET SYSTEM PROJECT -- APPLICATIONS PROCESS



has received less attention from industry than the undercarpet system. As yet, no private organizations are committed to commercializing it.

In 1976, Marshall Space Flight Center developed a complete, technically feasible prototype for baseboard FCC. T+E conducted some preliminary work to interest users and manufacturers in the system as part of the MSFC Flat Conductor Cable Commercialization Project.

The full development of baseboard FCC is expected to follow the commercialization of the undercarpet system as a natural extension of interest in the FCC concept.

2.0 THE UNDERCARPET FLAT CONDUCTOR CABLE SYSTEM

2.1 Background

In 1975 Technology + Economics, Inc. began its sponsoring of an effort to amend the National Electrical Code (NEC) to permit undercarpet undercarpet cable systems. Initial project work was conducted under contract to Johnson Space Flight Center as part of the "Urban Construction and Safety Project" (February, 1975 - April, 1976).

Under the direction of Marshall Space Flight Center, the current project has been a continuation of the earlier work.

2.2 System Testing and Code Rewrite

At its meeting in January, 1976, the National Electrical Code Committee Panel #7 undertook a preliminary consideration of our proposal to change the NEC to permit the undercarpet FCC system. The Panel voted to reject our proposal, and it became our task in the following month to understand what had been the shortcomings of our proposal and to develop a responsive course of action.

The Chairman of the Code-Making Panel was highly cooperative in communicating to us the deficiencies in our proposal. We came quickly to understand that the Panel's action did not constitute a flat rejection of the FCC concept, but was rather a result of certain specific deficiencies in the proposal and in our testing program that would be correctable in the coming months.

In the months of February and March, T+E and the industry group met repeatedly with itself and with Underwriters' Laboratories (UL) to arrive at a consensus about the situation. We worked closely with Underwriters' Laboratories initially, because of our subcontract relationship with them, and because of their close relationship with the Code Panel. (One of the most influential Code Panel members was supervisor of the UL group performing our Fact-finding Study). A first meeting of industry group representatives with UL produced considerable clarification of the Panel's concerns. The main concerns of the Panel were:

- 1) That the Code Article be rewritten to conform with their most recent style manual.
- 2) That the cable be required to be marked with additional information, and that the conductors be required to be clearly color-coded.

- 3) That the planned UL testing program be completed, notably an "Accelerated Maintenance and Use Test" of the in-place test layout.
- 4) That additional testing be undertaken to demonstrate the long-term stability and reliability of taps and splices.
- 5) Whether it is appropriate that carpeting with the system should require UL listing, as the original proposal suggested, or not.
- 6) That there be assurance of availability of effective tooling, such as "full-cycle" tooling, for making installations.

Three industry group meetings followed these clarifications, held on February 2, February 23, and March 4, 1976. These meetings considered a variety of alternative responses to the Code Panel's requirements, and arrived at the following Action Agenda:

- 1) T+E would work up a draft rewrite of the proposed Code amendment.
- 2) UL would be asked to proceed with their "Accelerated Use and Maintenance Test".
- 3) The decision was made to perform the tap-and-splice testing program at AMP, Inc. at Harrisburg, Pennsylvania, under UL supervision.

In May, David MacFadyen of T+E visited the Chairman of the NEC Code Panel to verify the proposed programs with him. On the basis of his comments, the programs proceeded.

T+E completed the Code Article rewrite in mid-June. The rewrite was reviewed in detail at the end of June in a meeting with the industry group, and a number of minor revisions were made. It was also reviewed both by a member of NEC's Central Correlating Committee and by the Chairman of Code Panel #7.

At about the same time that the Code Article was completed, UL began their final series of tests. The testing continued into mid-August, with no difficulties encountered. Upon completion of the testing, UL prepared a full Fact-Finding report to be presented to the NEC, and submitted it to the industry group for technical review.

The testing at AMP, Inc. was originally scheduled to begin in June. The test installation was in fact made at that time, but the connections failed to perform properly. The test assemblies were sent to AMP's Clearwater, Florida reserach facility for evaluation, and it was found that the cable that had been supplied had insulation that was of the wrong thickness. AMP subsequently obtained the proper cable, tested its connectors successfully with it, and reinitiated the test program.

During October the AMP connector testing was completed, and Underwriter's Laboratories completed their analysis of the raw results. Based on the Fact-Finding review, preliminary product listing requirements were generated at UL, and sent to T+E. was distributed to Code Panel members in September after undergoing technical review by Thomas and Betts and AMP, Inc.

2.3 International Association of Electrical Inspectors (IAEI) Meetings

As technical activities surrounding undercarpet testing moved toward a windup, project activity began to focus more closely on promotional effort for the undercarpet FCC system. The emphasis of project work became to promote acceptance of the FCC system by key sectors of the electrical and building industry establishment.

We had long recognized the International Association of Electrical Inspectors (IAEI) as a vital link in our information outreach effort. The Inspectors represent a strong voice in NEC decisionmaking, and are the implementers of the NEC in their respective locales.

In August we made arrangements to promote the undercarpet FCC system to the IAEI. Plans were made to send

representatives from T+E, AMP, Inc. and Thomas&Betts to the five regional meetings of the IAEI across the country. Floor presentations by T+E on the FCC Code Article were arranged at this time. Responsibility for building an FCC system exhibit was allocated to AMP's Clearwater facility (for a hardware component) and to T+E (for a backdrop display). Hospitality suites were arranged at all conference locations.

The round of meetings of the IAEI were completed by mid-October, marking the end of a major element of promotional effort on behalf of undercarpet FCC. There is consensus among project participants that the FCC project representatives were successful in accomplishing what they set out to do at the IAEI meetings. It was found that there exists strong interest in the concept of Flat Conductor Cable among inspectors and contractors.

The feedback received at IAEI meetings from electrical inspectors, contractors, and others tended to center around the installation-related questions that will undoubtedly arise as the FCC system comes into widespread usage. Typical questions concerned initial and retrofit procedures relative to different types of carpeting, retooling of electrician to insure that FCC will be properly installed, and specific marketing plans for the sale of FCC components.

There were many requests for further information on FCC. During December approximately fifty information packets were assembled at T+E and distributed.

2.4 Code Panel #7

During September arrangements were made by T+E, Thomas and Betts, AMP, INC. and Western Electric to visit all of the members of the NEC Panel #7 individually. The meetings were arranged for late October and November. Their purpose was to ensure the full support of the under-carpet FCC system by Code members before their December meeting.

T+E staff were responsible for two of those meetings - one with the National Electrical Contractors' Association (NECA) representative on the Panel, and the other with the National Association of Home Builders (NAHB) representative. The industry group representatives completed the remaining visits.

The project group agreed that the effort was fruitful. Useful feedback on the FCC system was received, and on the whole, Panel members were supportive of our work. Some changes were made in the formal Code Proposal as a result of suggestions made by Code members during the informal meetings.

In compliance with NEC requirements, T+E submitted final written materials (the revised Code Article and the final Underwriters Laboratories Fact-Finding Report) to Panel members by November 15. Individual letters to Panel members explained the major changes in the Code Article and summarized the supplementary testing described in the UL Report.

Final preparation for the Code Panel's December meeting involved preparing a short speech that was given by David MacFadyen on the Code Change, sending the system exhibit from AMP, Inc. in Clearwater, Florida to the meeting site in San Diego, and arranging for a hospitality suite where Code members could inspect the undercarpet FCC hardware before voting.

Representatives from T+E, Thomas and Betts, and AMP, Inc. took the responsibility for representing the FCC project group in San Diego.

2.5 Code Action

At the San Diego Code Panel #7 meeting (December 5 and 6) the initial voice vote on our proposed amendment was favorable. Ten members voted in favor of Code Article #328; none voted against it, and two abstained from voting. The favorable Code action was given with the stipulation that undercarpet FCC be restricted to use under carpet squares

rather than "all types of carpet or other suitable floor coverings" as stated in our proposal.

In the formal ballots of the Panel, which were compiled in late January, the two abstentions were changed to negative votes. In accordance with NEC rules, the dissenters set forth their technical justifications as part of the voting record. These objections are reviewed by the central NEC Correlating Committee, which weighs the strength of the negative arguments and makes the final decision to accept or reject the proposal. For each of the 2000-odd proposals acted on, the Correlating Committee votes on whether the vote record indicates a consensus that the proposed action should be accepted. Their decision is based not only on the number of dissenting votes, but also on the technical justifications for these votes. History indicates that in situations where there are two dissenting Panel votes, the Correlating Committee tends to go either way in its decision, depending on the strength of the negative argument. In the case of our proposal, the negative comments were not technically strong, and our assessment was that the Correlating Committee was likely to accept the proposal.

On February 15, the National Electrical Code Correlating Committee met and reviewed the proceedings of each Code-Making Panel. To the surprise of nearly everyone involved, the Correlating Committee determined that the Panel 7 vote did not constitute a consensus in favor of the proposal, and voted to table the proposal until 1981.

The February Correlating Committee vote represents the NEC's recommendation to its parent organization, the Electrical Section of the National Fire Protection Agency (NFPA). The NFPA will meet in May to formally adopt the National Electrical Code recommendations.

Outside of the scope of the current contract, T+E has been investigating the possibility of obtaining an early reversal of the Correlating Committee action either through the Correlating Committee itself or through the NFPA Electrical Section. The preliminary indication is that such a reversal would be difficult to achieve, but could in fact be achieved, given the necessary attention and effort.

Whatever the outcome of the 1978 Code activity, the implementation project has made the Flat Conductor Cable undercarpet wiring method visible to industry and has generated a momentum that will result in its ultimate adoption. The FCC industry group, despite the February setback, remains solidly committed to promoting the system's ultimate acceptance and marketing. The ultimate commercial success of this technology will represent a major positive impact for NASA's Technology Utilization Program.

2.6 Status Brochure

T+E is finalizing the layout and content of two status brochures on Flat Conductor Cable: one for undercarpet FCC, and one for baseboard FCC. After consultation with Marshall Space Flight Center officials, we concluded that the most useful type of document, for NASA's purposes, was a self-mailing single-sheet that can be used as a standard answer to information requests.

The brochures describe general Flat Conductor Cable system components, and installation procedures. They also reference sources of further information on both systems, list hardware, and give information on availability of components, where possible.

The same type of frontespiece is used for both the baseboard and undercarpet system brochures. An offset photograph of FCC in aerospace use is shown together with a 'down-to-earth' building application of the cable. The combination of photographs captures the essence of this technology transfer effort.

3.0 BASEBOARD FLAT CONDUCTOR CABLE SYSTEM

The major focus of project work and staff concern during this project has been on the undercarpet Flat Conductor Cable system. Nevertheless, the many opportunities we have had to discuss undercarpet FCC with members of the building and electrical industries has led naturally to a discussion of the baseboard system in many cases.

During the course of the current FCC effort for MSFC, we made preliminary contacts with manufacturers, sent out information packets on the baseboard system upon request, and, where relevant, attempted to direct industry interest to the commercialization potential of the baseboard FCC since the undercarpet system is adequately sponsored.

T+E feels that the initial contacts made on behalf of the baseboard system can be expected to pay off in the future. No commercial organizations are committed to the system now because of the dominance of the undercarpet system. Basically, industry is taking a "wait-and-see" attitude in order to verify the acceptance of the undercarpet system before committing effort to the baseboard system. The commercialization of the undercarpet system and the associated awareness of the FCC concept that it will catalyze can be expected to lead eventually to industry and user interest in "overall" FCC wiring systems - for both commercial and residential use. As undercarpet commercialization occurs, industry interest in developing the baseboard FCC system beyond its present prototype phase can naturally be expected to evolve.

The T+E Project Staff feels that its activity on behalf of baseboard FCC resulted in an overall increased awareness of the system. We feel as well that project activity ignited the sparks of interest in baseboard FCC that are the necessary precursor to active industry participation in its development.

4.0 REPORT APPENDICES

Article #328 - "Flat Conductor Cable Wiring
Systems:

(Code-change proposal submitted
to the National Electrical Code
Committee)

Sample Presentation speech to the International
Associated of Electrical Inspectors (IAEI)

ARTICLE 328-FLAT CONDUCTOR CABLE WIRING SYSTEMS

Type FCC

PART A. GENERAL

328-1. Scope. This Article covers a field-installed wiring system for branch circuits incorporating Type FCC cable and associated accessories as defined by the Article. The wiring system is designed for installation under carpeting and other suitable floor coverings.

328-2. Definitions.

(a) Type FCC Cable. Type FCC cable consists of 2 or more flat copper conductors placed edge to edge and separated and enclosed within an insulating assembly.

(b) FCC System. A complete wiring system for branch circuits that is designed for installation under carpet or other suitable floor coverings. The FCC system includes Type FCC cable and associated shielding, connectors, terminators, adapters, boxes, and receptables.

(c) Cable Connector. A connector designed to join Type FCC cables without using a junction box.

(d) Insulating End. An insulator designed to electrically insulate the end of a Type FCC cable.

(e) Top Shield. A grounded metal shield covering under-carpet components of the FCC system for the purposes of providing electrical safety and protection against physical damage.

(f) Bottom Shield. A shield mounted on the floor under the FCC system to provide protection against physical damage.

(g) Transition Assembly. An assembly to facilitate connection of the FCC system to other approved wiring systems, incorporating

(1) a means of electrical interconnection;

(2) a suitable box or covering for providing electrical safety and protection against physical damage.

(h) Metal Shield Connections. Means of connection designed to electrically and mechanically connect a metal shield to another metal shield, to a receptacle housing or self-contained device, or to a transition assembly.

328-3. Other Articles. The FCC system shall conform with applicable provisions of Articles 210, 220, 230, 250, and 300.

328-4. Uses Permitted.

(a) Branch Circuits. Use of FCC systems shall be permitted both for general purpose and appliance branch circuits, and for individual branch circuits.

(b) Floors. Use of FCC systems shall be permitted on hard, sound, smooth, continuous floor surfaces made of concrete, ceramic or composition flooring, wood, and similar materials.

(c) Walls. Use of FCC systems shall be permitted on wall surfaces in surface metal raceways.

(d). Damp Locations. Use of FCC systems in damp locations shall be permitted.

328-5 Uses Not Permitted. FCC systems shall not be used:

(1) outdoors or in wet locations; (2) where subject to corrosive vapors; or (3) in any hazardous location.

328-6. Branch Circuit Ratings.

(a) Voltage. Voltage between ungrounded conductors shall not exceed 300 volts. Voltage between ungrounded conductors and grounded conductor shall not exceed 150 volts.

(b) Current. General purpose and appliance branch circuits shall have ratings not exceeding 20 amperes. Individual branch circuits shall have ratings not exceeding 30 amperes.

PART B. INSTALLATION

328-10. Coverings. Floor-mounted Type FCC cable, cable connectors, and insulating ends shall be covered with carpeting or other suitable floor coverings.

328-11. Cable Connections and Insulating Ends. All Type FCC cable connections shall use connectors approved for the purpose, and installed in an approved manner such that electrical continuity, insulation, and sealing against dampness and

liquid spillage are provided. All bare cable ends shall be insulated and sealed against dampness and liquid spillage using insulating ends approved for the purpose.

328-12. Shields.

(a) Top Shield. A metal top shield shall be installed over all floor-mounted Type FCC cable, connectors, and insulating ends. The top shield shall completely cover all cable runs, corners, connectors, and ends.

(b) Bottom Shield. A bottom shield shall be installed beneath all Type FCC cable, connectors, and insulating ends.

328-13. Enclosure and Shield Connections. All metal shields, boxes, receptacle housings, and self-contained devices shall be electrically continuous to equipment grounding conductor of the supplying branch circuit. All such electrical connections shall be made with connectors approved for the purpose and in an approved manner. The electrical resistivity of such shield system shall be not more than that of one conductor of the Type FCC cable used in the installation.

328-14. Receptacles. All receptacles, receptacle housings, and self-contained devices used with the FCC system shall be approved for the purpose and shall be connected to the Type FCC cable and metal shields in an approved manner. Connection from any grounding conductor of the Type FCC cable shall be made to the shield system at each receptacle.

328-15. Connection to Other Systems. Power feed, grounding connection, and shield system connection between the FCC system and other wiring systems shall be accomplished in an approved manner in a transition assembly approved for the purpose.

328-16. Anchoring. All FCC system components shall be firmly anchored to the floor or wall using an adhesive or mechanical anchoring system approved for the purpose.

328-17. Crossings. Crossings of two Type FCC cable runs shall be permitted. Crossings of a Type FCC cable over or under a flat telephone cable shall be permitted. In each case, a grounded layer of metal shielding shall separate the two cables.

328-18. System Height. Any portion of an FCC system with a height above floor level exceeding 0.090 inches shall be tapered or feathered at the edges to floor level in a manner approved for the purpose.

328-19. FCC Systems Alterations. Alterations to FCC systems shall be permitted. New cable connectors shall be used at new connection points to make alterations. It shall be permitted to leave unused cable runs and associated cable connectors in place and energized. All cable ends shall be covered with insulating ends.

328-20. Polarization of Connections. All receptacles and connections shall be constructed and installed so as to maintain proper polarization of the system.

PART C. CONSTRUCTION

328-30. Type FCC Cable. Type FCC cable shall be approved for use with the FCC system and shall consist of 2, 3, 4, or 5 copper conductors. The insulating material of the cable shall be moisture resistant and flame-retardant.

328-31. Markings. Type FCC cable shall be clearly and durably marked on both sides at intervals of not more than 24 inches, with the information required by Section 310-11(a) and with the following additional information:

- (1) Material of conductors.
- (2) Maximum temperature rating.
- (3) Ampacity.

328-32. Conductor Identification.

(a) Colors. Conductors shall be clearly and durably marked on both sides throughout their length as specified in Section 310-10.

(b) Order. For a two-wire FCC system with grounding, the grounding conductor shall be central.

328-33. Corrosion Resistance. Metal components of the system shall be either: (1) corrosion resistant; (2) coated with corrosion resistant materials; or (3) insulated from contact with corrosive substances.

328-34. Insulation. All insulating materials in the FCC system shall be approved for the purpose.

328-35. Shields.

(a) Materials and Dimensions. All top and bottom shields shall be of designs and materials approved for the purpose. Top shields shall be metal. Both metallic and non-metallic materials shall be permitted for bottom shields.

(b) Resistivity. Metal shields shall have cross-sectional areas that provide for electrical resistivity of not more than that of one conductor of the Type FCC cable used in the installation.

(c) Metal Shield Connectors. Metal shields shall be connected to each other and to boxes, receptacle housings, self-contained devices, and transition assemblies using metal shield connectors approved for the purpose.

328-36. Receptacles and Housings. Receptacle housings and self-contained devices designed either for floor mounting or for in- or on-wall mounting shall be permitted for use with the FCC system. Receptacle housings and self-contained devices shall be approved for the purpose and shall incorporate means for facilitating entry and termination of Type FCC cable, and for electrically connecting the housing or device with the metal shield. Receptacles and self-contained devices shall comply with Section 210-7. Power and communi-

cations outlets installed together in an approved common housing shall be permitted in accordance with Section 800-3(a)(2) Exception No. 1.

328-37. Transition Assemblies. All transition assemblies shall be approved for the purpose. Each assembly shall incorporate means for facilitating entry of the Type FCC cable into the assembly, for connecting the Type FCC cable to round conductors, and for electrically connecting the assembly to the metal cable shields and to equipment grounding conductors.

Sample Flat Conductor Cable Presentation
to IAEI Section Meetings

●* Good Afternoon. My name is Peter Hogarth, and I represent a firm in Cambridge, MA, Technology and Economics, Inc. The subject of my presentation is Flat Conductor Cable wiring systems.

There's a proposal in the Preprint for a completely new Article - Article 328 - that would allow use of Flat Conductor wiring systems for power wiring. ○ This wiring method represents a definite departure from existing branch circuit wiring methods and it's appropriate that I give you a basic idea of the Code implications of these systems, in terms of what they're like, what they're intended to do, and what the current status of development is.

○ "Flat Conductor Cable," or "FCC," was originally developed for aerospace use. It is a very thin-profile cable with conductors that are rectangular in cross-section. A twelve-gauge equivalent, 20 AMP, 3-conductor FCC power cable is only 17 mils - or 1/64 inch-thick.

○ What we've done is to apply this cable to office floor receptacle wiring. Specifically, we've developed a system that you can lay directly on the office floor, underneath a carpet. The cable is shielded top and bottom, in a manner I'll describe. The maximum height of the entire assembly is 1/16-inch - which means that when installed under carpet, it's virtually undetectable.

*● denotes slide

2

• A group of 11 manufacturers has worked for two years to develop the FCC undercarpet system. My company, Technology and Economics, Inc., has coordinated the group, and is the sponsor of the Code proposal. We have a prototype system that has been extensively tested at UL and elsewhere. We will not have listed, commercially-available hardware until after Code approval. But, upon Code approval, at least two manufacturers with each market complete FCC systems.

• FCC undercarpet systems can fill important electrification needs. To put it briefly, FCC systems cope with changes in the office environment. The basic method of office wiring has been underfloor ducting. Underfloor ducted systems are good where a permanent, fixed layout is wanted. But, they are basically not designed to be changed, even though user needs change from time to time. Ducted systems can be changed by drilling new receptacle locations. • Here's a shot of the diamond-drilling operation. It's a costly, messy job, and you're still restricted to locations along existing conduits. The fact is that the needed changes are often not made - the user or tenant just doesn't want to go to the trouble. So, what does he do instead? He adapts the electrical layout to his present needs as best he can - and here is where the problem comes in. The problem is not with the ducted system, it's with the user's attempts to adapt that system. These adaptations - long extension cords, overloaded "Christmas-tree" outlets, and so forth - are at best inconvenient and at worst downright hazardous. Here are some slides that show what I mean:

- Here is a shot of one receptacle servicing two desks.
- Here's what happens when the receptacle stays where it was, but the desk moves back several feet.
- Here's an auxiliary loose-mounted receptacle located right underneath where somebody has to sit.
- Here's an attempt to create a new receptacle location using an over-the-carpet extension cord.
- Here's another well-known electrical device - the zipcord.

The FCC undercarpet system can cut down on these situations, because it's specifically designed to make electrical changes easy. It's totally flexible. Receptacles can be located anywhere on the floor; and then they can be moved anywhere else at any time. FCC can be installed as the original complete branch wiring system of a building. Even though it's changeable, it's also permanent for as long as it's needed. And, it's very strongly cost-competitive with existing methods.

When the time comes to change the wiring system, these changes can be made easily, safely, and at a price that a user is willing to pay. FCC can be used to alter existing ducted layouts as well as FCC layouts: for example, you can run an undercarpet FCC extension from an existing duct access location to a new receptacle. If undercarpet FCC is adopted, we'll see fewer unsafe, user-installed, jury-rigged adaptations, and more safe, professionally-installed, permanent adaptations. We feel it's something that's much needed for office electrification today.

I'll now show briefly how the undercarpet FCC system is put together. First, the basic configuration:

- o The flat conductor cable itself is composed of copper conductors laminated between layers of insulating plastic film. The total cable thickness is about 17 mils.
- o The cable is shielded top and bottom. A metallic top shield covers and protects the electrical components. It has a current-carrying capacity equal to a cable conductor, so that if a metal object penetrates the shield, the fault goes to ground and trips the circuit breaker. The shielding is 8-mil steel and is tough enough to prevent all ordinary accidental penetrations.

A non-metallic bottom shield protects the cable when it is laid on a rough floor. It also is adhesive-coated on both sides and anchors the system to the floor.

That's the concept. Now I'll show you some prototype hardware. This is not necessarily the exact form that commercially available hardware would take, but it shows the main features.

- o Cable connections use special hardware and are installed by a special tool. Here is a connector, ready to be attached to a cable run in a T-tap configuration.
- o Here is the connector tool in use.
- o Here is the completed connection. I'll show you exactly how that connection is made in a minute.
- o The connection is covered by a self-adhesive mylar patch that provides both insulation and moisture resistance.
- o The whole assembly is covered by metal shielding. Brass rivets provide electrical continuity. The shielding is grounded at receptacles and power feed sources.
- o Our prototype receptacles are adapted from conventional ones. Pigtail leads run from the FCC termination to the receptacle.

I want to explain some more about the technique for making a T-tap. This connection method promises to be a uniquely positive and reliable way of making branch circuit connections.

- o Again, here is a shot of the T-tap device. In the next slide, we will look closely at one end of those three brass connector strips.
- o Here is the closeup. You'll see two things: a pair of large prongs, and in between them, a set of four smaller prongs. The small prongs are what make the actual electrical contact with the cable. The large prongs are mechanical in function - they simply hold the assembly together. I'll show you how this works:
- o Here, the connector is positioned under the FCC cable conductor.
- o Here, the large prongs are forced all the way through the cable insulation. The smaller prongs pierce the insulation under the conductor.
- o Here, the large prongs fold tightly over the cable conductor. The small prongs shear away the cable insulation and make a tight, spring-loaded contact.

This type of connection is positive and permanent, and reduces the chances of installer error. The tooling and manufacturing process takes away many of the possible sources of error. We have to depend less on the installer's skill to ensure safe connections.

I'll conclude with a brief status report on the FCC system and the Code proposal. As you recall, we have a proposed new Code Article before the NEC, Article 328. o This proposal is supported by an extensive Fact-Finding investigation that has been conducted by Underwriters' Laboratories. o This is a shot

of UL's large-scale FCC testroom, during the installation of the Test system. The system has been comprehensively tested under a variety of conditions. UL has also performed a large number of bench-top tests of the cable and the shielding. The FCC system has stood up well to this test program. In many cases, the FCC cable has performed dramatically better than equivalent conventional cables.

o At its first round of meetings last January, NEC Panel No. 7 rejected our proposal. This was primarily because, at the time, the testing program was not complete. The Panel did not find fault with the system in itself, and gave us a specific list of deficiencies in our proposal. We have worked since that time to correct the deficiencies. We are hopeful and optimistic that the Panel will reverse its position and accept our proposal this December.

If we do get approval, UL will go ahead immediately to develop listing requirements for FCC hardware. FCC undercarpet wiring systems would become available commercially about two years from now.

To sum up: we have a Code-change proposal that allows systems like the one that I've described. There's a good chance the proposal will be accepted, and that you'll be seeing FCC systems. This is your chance to give us feedback about what you think of this system. At the previous section meetings we've been to we've received many good, helpful comments.

I'd really appreciate the chance to talk to as many of you
as possible.

Thank you. I'll answer any questions you have.